Performance Evaluation Of Surface Integrity During Electrical Discharge Machining Of Oil Hardened Non Shrinkable Steel

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Abstract: Electro-Discharge Machining (EDM) is a non-conventional machining method that has gained significant importance in the recent years due to the various advantages it contains. EDM process comprises of removal of material by erosion through series of electric spark. The material used in the study, OHNS O-series, was subjected to EDM to evaluate the mechanical and surface property changes after machining using Jatropha BD as dielectric fluid. The properties under consideration were Surface roughness, Ultimate Tensile Strength, and Surface hardness. A number of samples were machined by EDM process, by selecting the suitable input machining parameters. The input parameters of EDM that are varied are gap current, Pulse on-time (T_{on}), and Pulse-off time (T_{off}). The samples are then tested for surface roughness, surface hardness, and Ultimate Tensile Strength (UTS).The tests revealed that the Surface roughness increases with increase in Gap current, Pulse- on time and decreases with increase in pulse-off time. This increase in surface roughness results in decrease in Ultimate tensile strength, because it results in formation of micro cracks over the surface of machined samples. It also revealed that the hardness increases due to quenching occurring due to the dielectric fluid present.

Keywords: EDM, Machining parameters, Gap current, Pulse-on time, Pulse-off time, Surface roughness, Surface hardness, Ultimate tensile strength.

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1 INTRODUCTION:

Non-conventional machining methods are the ones that are not commonly used to machine materials used in the industry, due to various reason such as high initial cost, high power requirements, etc. This process uses electric discharges or sparks to machine material. These discharges are set between the workpiece and the tool electrode. A dielectric fluid is used in which both of these components, viz. workpiece and the electrode, are such that these two do not make a physical contact with each other. A voltage is applied across the tool electrode and the workpiece used. This voltage is increased linearly upto a point where the intensity of the electric field around the tool electrode submerged in the dielectric becomes greater than the dielectric strength of the dielectric used. Due to this, the voltage breaks the barrier and finally electric discharges are produced emerging from the tool electrode and impacting on the surface of the workpiece. In this way, the discharges strike the surface and remove the material by increasing the localized temperature. These discharges are not continuous, but rather repetitive. Due to the removal of material, a constant gap needs to be maintained between the tool electrode and the workpiece. If this is not maintained the intensity of the electric field may lower, and the discharges may stop. Therefore, it is necessary to control the gap between the tool electrode and the workpiece. This is done with the help of a servo mechanism, which lowers the tool electrode into the workpiece as the material removal takes place.

2 METHODOLOGY:

Material:

This alloy of steel can be categorized as O1,O2,O6 and O7 type. The chemical composition for this alloy of OHNS is as follows: 0.90% (Carbon), 1.0–1.4% (Manganese), 0.50% (Chromium), 0.50% (Tungesten), 0.30% (Silicon), 0.20% (Vandium). OHNS O-series, is in a hexagonal closely packed crystalline structure, which is in the Alpha-Beta form or can also be in the body centered cubic structure, which is in the beta form [1].This specific alloy was chosen on the basis of its applications in various industries and its machinability. It finds applications in various industries such as the Aerospace industry, Medical field, Automobile industry, Ocean Engineering, etc. [11]..

Fig2.1 *Shear cut samples*

Tool electrode details:

Electrolytic copper electrode (99.9%) has been used as tool material for the machining of the samples. A copper rod of 25mm diameter was used for machining of the workpiece.

Process Selection:

The process to be selected to machine the test samples was Electro-Discharge Machining (EDM). This process was selected considering the research to be conducted on this particular machining process. The tool used for the machining was made of 99.9% electrolytic copper. The diameter of the tool was 25mm, which was used to EDM a small circle on the sample up to a depth of 0.5mm. The samples were divided into three sets viz. Set A, Set B, and Set C. Each Set had four machining parameters amongst which one was varied for each sample in the sample. The four machining parameters selected were Current (in A), T_{on} (in µs), T_{off} (in µs), and Voltage (in V). Set A had a total of seven samples with three fixed machining parameters, viz. Ton (300 µs), Toff (4 µs), Voltage (70 V), and one varying cutting parameter, Current. Set B had a total of seven samples with three fixed machining parameters, viz. Current (20 A), Toff (4 µs), Voltage (70 V), and one varying parameter, Ton. Set C had a total of seven samples with three fixed machining parameters, viz. Current (20 A), Ton (200 µs), Voltage (70 V) and one fixed cutting parameter, Toff. Voltage was not varied in any of the sets as an increase in the Voltage led to a greater Tool wear rate and a decrease in the Voltage led to no machining action of the material.

Experimental setup:

Fig *2.2 Machining of samples*

Workpiece details:
The specifications of the OHNS O-series workpiece are as given below:

- Work piece size: 100×25x5 mm
- Shape: Rectangular
- Thickness: 5mm
- Cutting angle: Vertical
- Location for machining: Center of work table
- Stability control: servo mechanism
- Tool electrode: pure electrolytic copper (99.9%)
- Polarity: Tool negative & Workpiece positive

Surface roughness testing:
The machined samples of selected material would be tested for surface roughness using appropriate method to check its relation with process parameters.

Tensile Testing:
The machined samples of selected material would be tested for Ultimate Tensile strength using appropriate method to check its relation with process parameters.

Hardness Testing:
The machined samples of selected material would be tested for surface hardness using appropriate method to check its relation with process parameters.

Askar microns V3525 die sinking electric discharge machine was used to carry out Machining of the samples. Servo mechanism controls the servo head gap voltage. It also controls the positive polarity, in the Z axis. Accuracy of 5 micrometer can be observed in all the three axes. Electric discharges emerged from the tool electrode and impacted on the workpiece, which led to material removal. As the material is removed, servo mechanism kicked in to maintain the gap between the workpiece and the tool electrode. It also controls the downward movement of the electrode. The dielectric medium used for flushing purpose is EDM 30 grade oil. During experiment side flushing is used to flush out removed material.

Fig 2.3 *Surface roughness testing*

Fig 2.4 *Samples after Tensile testing*

Machining input parameters:

Table 3.1 Machining parameters for Set A

Current	Ton	Toff	Voltage
14	300	4	70
15	300	4	70
16	300	4	70
18	300	4	70
20	300	4	70
22	300	4	70
25	300	4	70

Table 3.2 Machining parameters for Set B

Current	Ton	Toff	Voltage
14	300	4	70
15	300	4	70
16	300	4	70
18	300	4	70
20	300	4	70
22	300	4	70
25	300	4	70

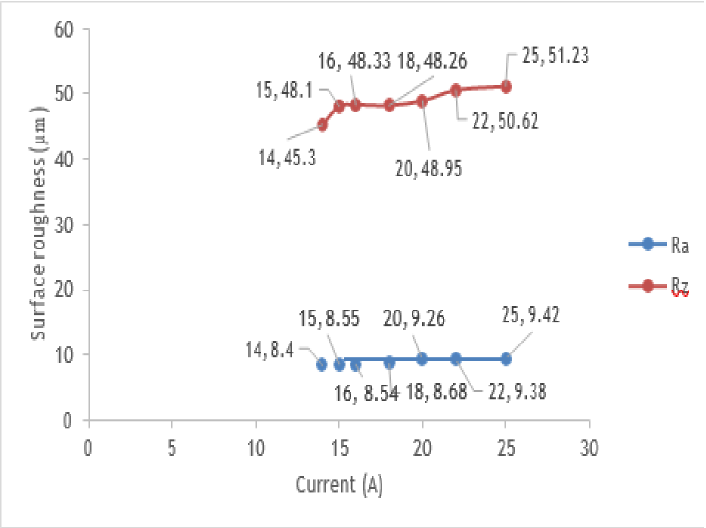
Table 3.3 Machining parameters for Set C

Current	Ton	Toff	Voltage
20	200	3	70
20	200	4	70
20	200	5	70
20	200	6	70
20	200	7	70
20	200	8	70
20	200	9	70

3 RESULTS:

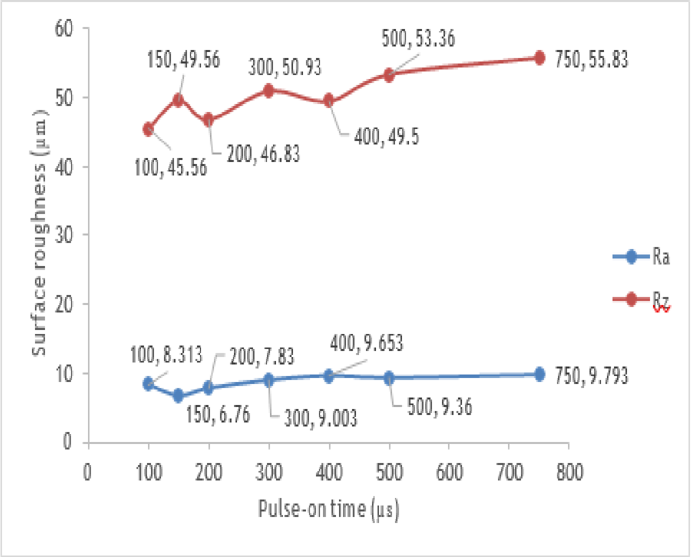
Effect of Gap current on Surface roughness:

Following is the test graph obtained for the surface roughness testing conducted on samples of Set A:



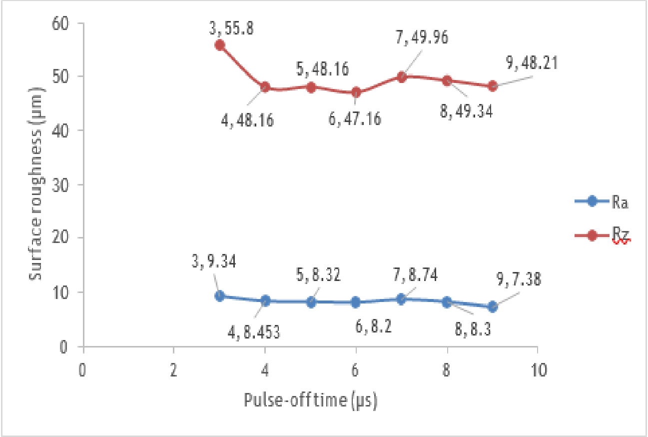
3.1: *Surface Roughness vs. Gap Current*

Effect of Pulse-on time on Surface roughness:
Following is the test results obtained for the surface roughness testing conducted on samples of Set B:



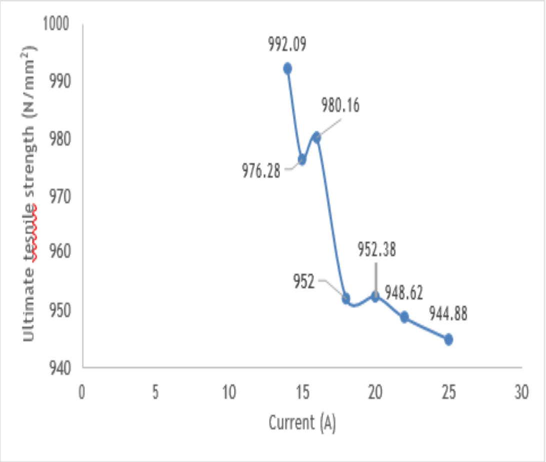
***Graph 3.**2: Surface roughness vs. Pulse on time (Ton)*

Effect of Pulse-off time on Surface roughness:
Following is the test results obtained for the surface roughness testing conducted on samples of Set C:

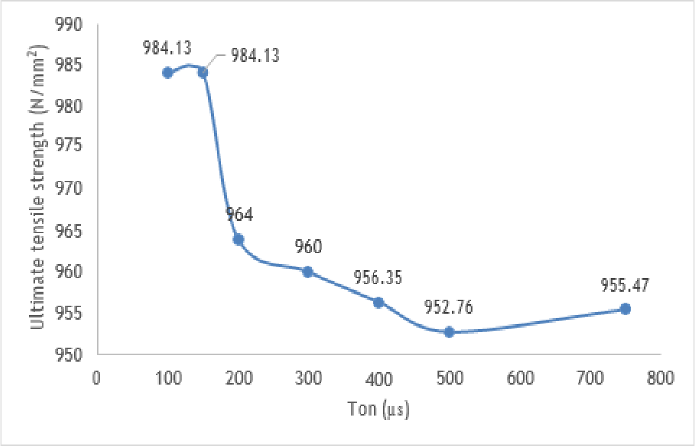


***Graph 3.3** Surface roughness vs. Pulse off time (Toff)*

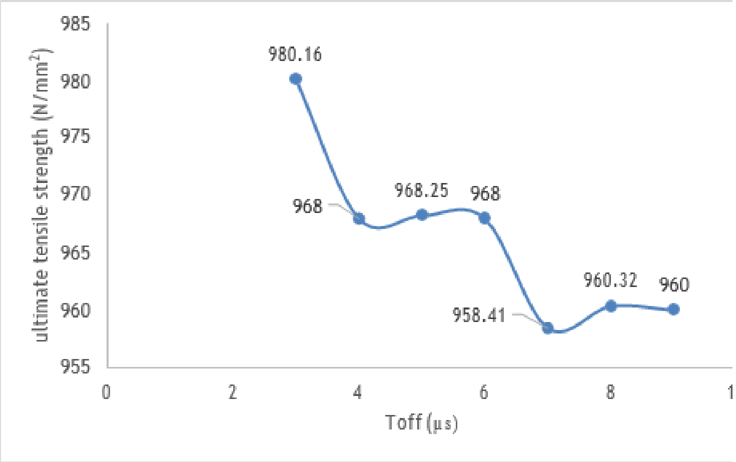
Effect of Machining input parameters on Tensile testing:



***Graph 3.4** Ultimate Tensile Strength vs. Gap current for Set A*

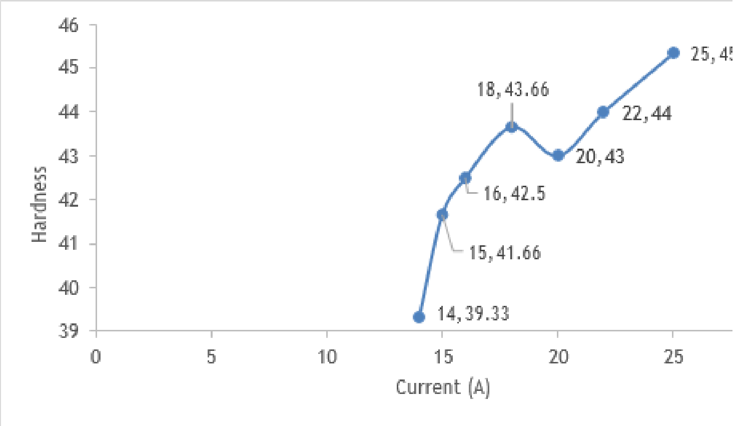


***Graph 3.**5 Ultimate Tensile Strength vs. Pulse on time, Ton for Set B*

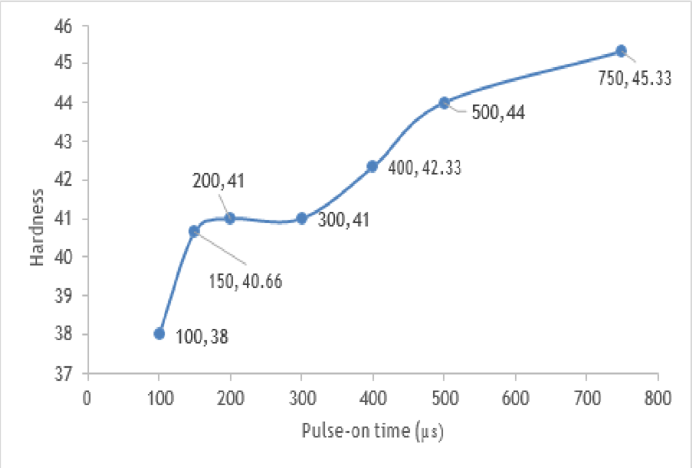


Graph 3.6 *Ultimate Tensile Strength vs. Pulse-off time, Toff for Set C*

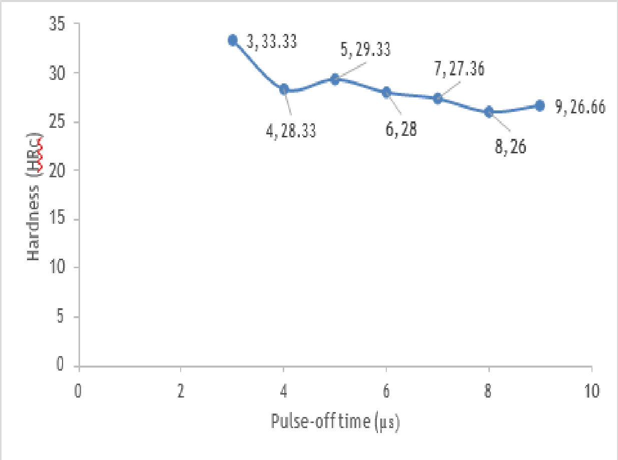
Effect of Gap current on Surface hardness:
Following are the test results obtained for the Rockwell hardness testing conducted



Graph 3.7 *Hardness (H R c) vs. Gap current (Amp) for set A*



Graph 3.8 *Hardness (HRc) vs. Pulse-on time (µs) for set B*



Graph 3.9 *HRC (Set C) vs. Pulse-off time (µs) for set B*

CONCLUSION:

Based on the data collected and analyzed by the different tests conducted on the machined samples by EDM process, the following observations were drawn:

- It is observed that as the current is increased, surface roughness goes on increasing. The maximum value of surface roughness obtained was 51.23µm at gap current of 25 A.
- As the pulse-on time is increased, the surface roughness of the workpiece goes on increasing. The maximum value of surface roughness obtained was 55.83 µm at pulse on-time of 750 µs.
- It is observed that as the pulse-off time is increased, the surface roughness decreases. The maximum value of surface roughness obtained was 55.38 µm at a pulse-off time of 3 µs.
- The Ultimate tensile strength decreases with increase in gap current. The maximum value of Ultimate tensile strength obtained was 992.09 N/mm^2, at a gap current of 15 A.The Ultimate tensile strength decreases with increase in pulse-on time. The maximum value of Ultimate tensile strength obtained was 984.13 N/mm^2, at a pulse-on time of 100 µs.
- The Ultimate tensile strength decreases with increase in gap current. The maximum value of Ultimate tensile strength obtained was 992.09 N/mm^2, at a gap current of 15 A.
- Hardness was observed to increase with increase in gap current. The maximum value of hardness of 45.33 HRc, was obtained at a gap current of 25 A.
- Hardness was observed to increase with increase in pulse-on time. The maximum value of hardness of 45.33 HRc, was obtained at a pulse-on time of 750 µs.
- Hardness was observed to increase with increase in gap current. The maximum value of hardness of 33.33 HRc, was obtained at a pulse-off time of 3 µs.

FUTURE SCOPE:

The effects of the input parameters of EDM on the mechanical properties of Oil Hardened Non Shrinkable Steel were studied in this paper. The biocompatibility of Oil Hardened Non Shrinkable Steel allows it to be used in medical field. The study conducted in this paper is further going to be used to test the fatigue strength after machining, and finally be implemented in a biomedical application.

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